

Evolution of morphological and functional parameters of the right ventricle after mitral valve surgery

Maria- Luiza Cobzeanu^{1,2}, Andra Oancea^{1,3*}, Cristina Furnică^{1,4*}, Raluca Ozana Chistol^{1,5}, M. Enache^{1,5}, A. Țăruș^{1,5}, Flavia Corciova⁵, Alina- Cristina Iliescu⁵, Elena Deju⁵, Gr. Tinică^{1,5}

¹ Faculty of Medicine, “Grigore T. Popa” University of Medicine and Pharmacy, 700115 Iasi, Romania

² Department of Radiology, “Sf. Spiridon” County Clinical Emergency Hospital, 700111 Iasi, Romania

³ Internal Medicine Clinic, “Sf. Spiridon” County Clinical Emergency Hospital, 700111 Iasi, Romania

⁴ Institute of Forensic Medicine, 700455 Iasi, Romania

⁵ Cardiovascular Disease Institute, 700503 Iasi, Romania

Abstract:

EVOLUTION OF MORPHOLOGICAL AND FUNCTIONAL PARAMETERS OF THE RIGHT VENTRICLE AFTER MITRAL VALVE SURGERY Right ventricular (RV) dysfunction has a high prevalence in patients with mitral pathology and represents an important predictor of negative prognosis after surgical treatment. **Aim:** to study the mid-term postoperative effect of mitral valve repair or replacement on the right ventricular function. **Material and methods:** The mid-term postoperative evolution of the right ventricular function of the 152 patients with mitral valve disease, treated by mitral valve replacement or repair at the Cardiovascular Institute from Iasi was analyzed. **Results:** Echocardiography performed immediately postoperatively revealed a transient alteration of biventricular function, although RV was more vulnerable to operative stress. In the early postoperative period, the severity of tricuspid regurgitation (TR) and pulmonary hypertension (PH) improved, but tricuspid annular plane systolic excursion (TAPSE) decreased. At 1 year after surgery, there was a significant improvement in NYHA class, a slight one regarding TR and the significant improvement of PH was maintained. It was also found a reverse RV remodeling, demonstrated by an increase in TAPSE which was less than 17 mm in 12 cases (13.64%) compared to 15 cases (17.05%) in the early postoperative period. The trend toward reverse RV remodeling continued 2 years after surgery with constant maintenance of the severity of TR, PH and NYHA classification. At 3 years after the intervention, a minimal dilation of the right ventricle was found with the maintenance of TAPSE stationary. **Conclusions:** The present study highlights the impact of mitral valve surgery on the evolution of the RV.

Keywords: RIGHT VENTRICLE, MITRAL VALVE, TAPSE, CARDIAC SURGERY

INTRODUCTION

The prognostic value of RV (right ventricle) function in cardiac surgery is an intensely debated topic, but incompletely elucidated in the literature. In cardiac surgery, the prognostic impact was initially highlighted in patients with coronary artery disease (CAD) and severe LV (left ventricular) dysfunction in whom the risk of mortality after coronary artery bypass graft (CABG) increases significantly in case of biventricular dysfunction (1). Subsequently,

***Corresponding author:** Cristina Furnică e-mail: cristinafurnica@yahoo.com; Andra Oancea: e-mail: andra.oancea@umfiiasi.ro

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a decrease in long-term survival was demonstrated in patients with RV dysfunction and ischemic heart disease surgically treated with LV reconstruction and CABG. (2)

Despite this evidence, RV function is currently not recognized as a prognostic factor in the guidelines for management of valvular heart disease, especially mitral regurgitation. Moreover, the RV function is completely ignored by major risk assessment systems in cardiac surgery such as STS (Society of Thoracic Surgeons) and EuroSCORE (European System for Cardiac Operative Risk Evaluation Score) (3,4).

Mitral valve pathology causes an increase in volume and pressure in the left atrium, which causes, retrogradely, an increase in pulmonary venous pressure and, through it, an increase in pulmonary capillaries pressure and pulmonary arterial pressure. Thus, in the advanced stages of mitral pathology there is an increase in afterload and tele diastolic pressure of RV (5).

The aim of the current study was to evaluate the mid-term postoperative evolution (1,2 and 3 years after surgery) of right ventricular function in patients with mitral valve pathology (stenosis, regurgitation or mitral disease) treated by mitral valve replacement or repair.

MATERIAL AND METHODS

A prospective, unicentric, cohort study evaluating the mid-term postoperative evolution (1, 2 and 3 years) of RV function was performed between January 2018 and December 2020 in a group of 152 patients with mitral pathology (stenosis, regurgitation or mitral disease) treated by mitral valve replacement or repair at the Institute of Cardiovascular Diseases “Prof. Dr. George I.M. Georgescu” Iași (IBCV).

The exclusion criteria included incomplete medical records, absence of postoperative echocardiographic information or the refusal of patients to be included in the study.

The study was approved by the Ethics Committee of the “Gr. T. Popa” University of Medicine and Pharmacy, Iasi and the Ethics Committee of the Cardiovascular Institute from Iasi. The patients were informed about the study and signed an informed consent.

The analysis of the early postoperative evolution was performed for the entire group of 152 patients. The following echocardiographic parameters and threshold values were used to assess RV dysfunction: mid-cavity RV end-diastolic diameter > 35 mm, RV / LV end-diastolic diameter ratio > 0.9, inferior vena cava (IVC) diameter > 21 mm; right atrium (RA) diameters > 53 mm (long axis) and > 44 mm (short axis), tricuspid annular plane systolic excursion (TAPSE) < 17 mm, maximal trans-tricuspid systolic pressure gradient (dPmax), pulmonary hypertension (PH) severity.

Echocardiographic evaluation of patients was performed using Siemens Acuson X300 and General Electric Vivid E9 devices, preoperative, immediate and distant postoperative (1,2 and 3 years) by cardiologists from IBCV. Echocardiographic parameters determined in two-dimensional, M mode, pulsed Doppler, color, spectral, continuous or tissue were measured according to the recommendations of the American Society of Echocardiography and the European Association of Echocardiography.

Pre-, intra-, and postoperative data of the patients included in the study was entered into a database using Microsoft Excel 365 for Mac OS X and was statistically analyzed with SPSS 24 for Mac OS X. Continuous variables are expressed as mean $\pm$ standard deviation. Categorical variables are expressed as total

number of cases and percentages. Groups were compared using the χ^2 or Fisher exact test for categorical variables and the ANOVA / Student's t-test and Wilcoxon–Mann–Whitney U / Kruskal Wallis test for continuous variables based on their distribution. Normality was checked using the Kolmogorov–Smirnov and the Shapiro–Wilk W tests. A p value < .05 was considered statistically significant. introduced into a database using Microsoft Excel and MedCalc 19.2.6 and were statistically analyzed using IBM SPSS Statistics 24 program for Mac OS X. The results are presented as tables, graphical representations and dedicated statistical tests. Continuous variables are presented as mean $\pm$ standard deviation and

the normality was checked using Shapiro–Wilk W and Kolmogorov–Smirnov tests. Continuous variables were compared, after checking the normal distribution, using the t-student and ANOVA tests. Subsequently, the association of the different variables was verified with the Pearson correlation test.

RESULTS: The study group included a total of 152 patients with mitral valve surgery whose demographic and clinical data are presented in table I. (DM-diabetes mellitus, AHT-arterial hypertension, NYHA-New York Heart Association, TAPSE - Tricuspid annular plane systolic excursion, TRI - Tricuspid regurgitation, PH-pulmonary hypertension, IVC-CI-Respiratory Collapse of the Inferior Vena Cava.)

TABLE I Preoperative demographic and echocardiographic parameters

Parameter	Value
Age (years)	59 $\pm$ 11.28
Gender (no, %male)	78 (51.3)
DM (no, %)	18 (11.8)
Dyslipidaemia (no, %)	36 (23.7)
AHT (no, %)	52 (34.2)
Neurological dysfunction (no, %)	16 (10.5)
Angina (no, %)	6 (3.9)
Mitral pathology type	Mitral regurgitation – 105 (70%) Mitral stenosis – 12 (8%) Mitral disease – 33 (22%)
NYHA (no, %)	NYHA 0/I – 11 (7.2%) NYHA II – 22 (14.5) NYHA III – 108 (71.1) NYHA IV – 11 (7.2)
Atrial fibrillation (no, %)	107 (70.39)
Prior cardiac surgery (no, %)	5 (3.29)
RV diameter	32.45 $\pm$ 5.36 mm
TAPSE	21.94 $\pm$ 6.49 mm
Tricuspid regurgitation (no, %)	Absent – 21 (13.82) I – 61 (40.1) II - 51 (33.6) III – 18 (11.8) IV – 1 (0.7)
PH (no, %)	Absent– 36 (23.7) Mild – 23 (15.1) Moderate – 50 (32.9) Sever – 43 (28.3)
Absent IVC-CI	3 (1.97%)

Mitral valve replacement was performed in 78 cases (51.32%), using a bioprosthetic valve in 8 patients (10.26%) and a mechanical valve in 70 patients (89.74%). In 74 cases (48.68%) the repair of the valve was possible. Additional interventions were performed in 37 cases (24.34%) and were represented by left atrial appendage exclusion (resection or suture) in 28 cases, endocarditis vegetation excision - 2 cases, septal myectomy - 1 case, CABG - 1 case, Bentall intervention - 1 case, surgical ablation of atrial fibrillation - 1 case. Postoperative complications were rare and mainly represented by atrial fibrillation - 45 cases (29.61%), atrioventricular block - 2 cases (1.32%), ventricular extrasystoles - 1 case (0.66%), remitted ventricular fibrillation - 1 case (0.66%). No postoperative death was recorded in the studied group.

Transthoracic echocardiography performed the day after surgery revealed a transient alteration of biventricular function, resulting in an insignificant reduction of left ventricular ejection fraction (LVEF) and fractional shortening (FS), and significant reduction of TAPSE. RV was more vulnerable to operative stress compared to LV. Although TAPSE decreased early in the postoperative period, the severity of tricuspid regurgitation decreased between the 2 determinations, **reduction being statistically significant at the χ^2 test** ($p < 0.001$). The finding was similar in the case of PH, which also decreased significantly in severity ($p < 0.001$). The comparative analysis of the morphological and functional parameters of RV is detailed in table II.

TABLE II Comparison of morphological and functional parameters of RV

Parameter	Preoperative (152)	Postoperative (152)	p
LA antero-posterior diameter (mm)	60.04±14.29	57.09±11.19	0.01
Maximal trans-tricuspid systolic pressure gradient (dPmax) (mmHg)	40.47±16.25	24.45±8.56	<0.0001
RA diameter (long axis) (mm)	51.24±10.17	48.59±7.67	0.0001
RA diameter (short axis) (mm)	43.64±8.83	41.86±7.18	0.009
Mid-ventricular RV diameter (mm)	31.90±5.79	32.12±6.03	n.s.
TAPSE (mm)	22.20±9.98	14.59±3.57	0.0001
RV Diastolic diameter / LV diastolic diameter	0.62±0.16	0.67±0.12	<0.0001

Thus, there was a significant immediate postoperative improvement of RV preload and afterload in the sense of a decrease of the antero-posterior diameter of the LA, long and short axis RA diameters and dPmax. The atria were the first cavities to show a tendency to reverse remodeling, while the ventricles showed minimal postoperative dysfunction.

Preoperatively, 43 patients (34.4%) had RA dilation compared to 27 patients (21.26%) postoperatively, as opposed to RV

dilation identified in 24 cases preoperatively (20.34%) and 29 (27.88%) postoperatively. A TAPSE value below the threshold of 17 mm was quantified in 15 cases (16.13%) preoperatively and in 25 cases (64.10%) postoperatively.

The postoperative evaluation at 1 year was performed on a subgroup of 88 patients who presented for control. Of the remaining 64 patients, 55 were lost to follow-up, and 9 died in the first postoperative year. At 1 year after surgery, there was a significant

improvement in NYHA class compared to the preoperative status. The NYHA class was not evaluated early postoperatively due to the bias represented by the general condition of the patient. NYHA class improved significantly ($p < 0.0001$) one year after surgery with only 9 cases (10.34%) in NYHA class III and no case in NYHA class IV. Tricuspid regurgitation improved slightly at 1 year compared to the early postoperative period by regression from grade III to grade II in one patient and the disappearance in another patient. There were no statistically significant difference between the severity of postoperative tricuspid regurgitation and at 1 year ($p > 0.05$) (fig 1).

Table III shows a continuation of the regression of the LA antero-posterior diameter, which correlates with the remission of PH. The LV functional parameters did not undergo significant changes while RV function improved with increasing TAPSE and decreasing mid-ventricular diameter.

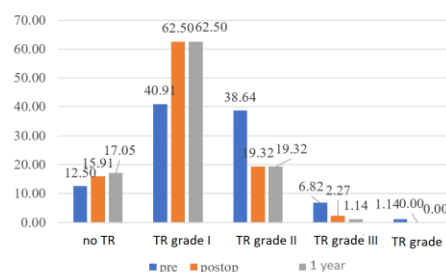


Fig. 1. Evolution of the severity of tricuspid regurgitation 1 year after surgery

As for PH, the significant improvement was maintained at 1 year postoperatively with significant variations ($p = 0.0025$) (fig. 2).

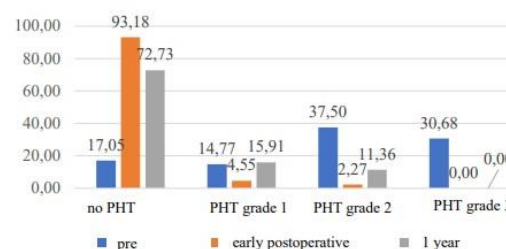


Fig. 2. Evolution of the severity of pulmonary arterial hypertension 1 year after surgery

TABLE III Comparison of morphological and functional parameters of LV and RV at 1 year vs. early postoperative time

Parameter	Preoperative (152)	Postoperative 152	1 year (88)	P
LV FS (%)	29.27±3.56	26.73±2.6	27.78±4.6	n.s.
LVEF (%)	56.93±9.4	50.16±8.81	52±8.58	n.s.
Antero- posterior diameter LA (mm)	60.48±13.48	57.09±11.19	53.09±11.91	0.0120
dPmax (mmHg)	40.41±13.87	24.45±8.56	27.11±8.6	0.0283
RA diameter (long axis) (mm)	51.11±9.71	48.59±7.67	48.79±6.88	n.s.
RA diameter (short axis) (mm)	44.15±8.70	41.86±7.18	43.95±7.12	n.s.
Mid-ventricular RV diameter (mm)	33.2±6.03	32.12±6.03	31.86±4.85	0.001
TAPSE (mm)	22.35±7.43	14.59±3.57	18.14±3.2	0.018
RV diastolic diameter / LV diastolic diameter	0.62±0.16	0.67±0.12	0.66±0.1	n.s.

Using the previously defined threshold values, we quantified a constant

number of patients with RA dilation between the early postoperative period and 1 year,

respectively 20 cases (22.73%). Similarly, at 1 year, 20 patients with RV dilation were identified (22.73%) versus 19 in the early postoperative period (21.59%). Functional parameters of RV underwent changes, especially TAPSE which was less than 17 mm in 12 cases (13.64%) at one year compared to 15 cases (17.05%) immediately postoperatively.

Between one-year and 2-year controls, 2 patients died and 38 were lost to follow-up, with only 48 patients presenting for control. The severity of heart failure continued to decline even 2 years after surgery. Tricuspid regurgitation was stable between the 2 evaluations, at 1 and 2 years, with the absence of significant or severe regurgitation (Fig. 3).

Similar to tricuspid regurgitation, pulmonary hypertension did not register significant differences between the 2 evaluations, at 1 year and 2 years, the results of the surgery being stable over time.

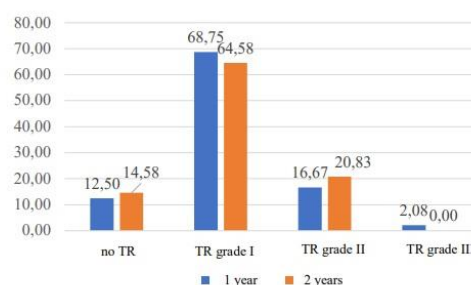


FIG. 3. Evolution of the severity of tricuspid regurgitation 2 years after surgery

Table IV shows a new comparison of morphological and functional echocardiographic parameters that display an increase in the maximum trans-tricuspid gradient in the setting of an improved RV function (significant increase in TAPSE and decrease in mid-ventricular diameter).

TABLE IV Comparison of morphological and functional parameters of LV and RV at 2 years vs early postoperative time and control at 1 year

Parameter	Preoperatively	Postoperatively	1 year	2 years	P
LV FS (%)	30±4.03	26.5±2.35	27.72±4.29	27.06±2.51	n.s.
LVEF (%)	56.77±7.95	50.32±9.52	51.21±9.24	50.75±9.31	n.s.
LA antero-posterior diameter (mm)	60.29±13.51	57.44±12.10	55.36±12.45	54.62±10.82	n.s.
dPmax (mmHg)	39.16±12.93	24.25±6.38	25.86±9.31	28.18±10.23	<0.0001
RA diameter (long axis) (mm)	51.47±9.81	48.33±6.76	48.47±7.52	49.62±8.62	n.s.
RA diameter (short axis) (mm)	44.66±8.19	42.38±6.24	43.55±8.10	44.84±9.13	n.s.
Mid-ventricular RV diameter (mm)	33.80±6.27	32.78±5.46	31.93±4.58	31.24±6.17	0.0124
TAPSE (mm)	22.91±9.09	15.54±2.9	18.8±3.44	20±1.98	0.004
Diastolic diameter RV/diastolic diameter LV	0.65±0.19	0.69±0.12	0.65±0.10	0.62±0.12	0.040

Improvement of RV function is associated with a paradox at the atrial level, with the number of patients with RA dilation increasing from 9 patients at 1 year (18.75%) to 15 (31.25%) 2 years after surgery while the

number of patients with RV dilation decreased from 11 (22.92%) to 7 (14.58%) like the number of patients with TAPSE <17 mm (from 4 patients at 1 year to 3 patients at 2 years).

Between 2 years and 3 years postoperatively, 2 more patients died and 12 were lost to follow-up, 34 patients presenting for control at 3 years. The NYHA class remained relatively stable, with only one patient regressing from class III to class II. The evolution was similar for pulmonary

arterial hypertension, patients with maximum moderate PH. TR registered a minimal progression with the transition from mild to moderate in 2 cases and the appearance of significant PH in one case, without any severe form.

TABLE V Comparison of morphological and functional parameters of LV and RV

Parameter	1 year	2 years	3 years	p
LV FS (%)	26.2±4.25	27.67±2.58	25.53±4.78	n.s.
LVEF (%)	50.03±10.53	50.31±10	50.88±11.64	n.s.
Antero- posterior diameter LA (mm)	53.85±7.39	53.32±9.81	57.24±9.23	0.05
dPmax (mmHg)	25.32±8.52	28.14±9.77	27.72±8.36	n.s.
RA diameter (long axis) (mm)	47.88±6.37	48.72±8.69	50.65±8.05	0.0003
RA diameter (short axis) (mm)	42.41±7.26	44.24±9.34	46.12±7.53	n.s.
Mid-ventricular RV diameter (mm)	31.81±4.45	29.72±4.20	32.8±3.97	0.0016
TAPSE (mm)	18.4±3.22	19.69±2.04	20.07±2.64	n.s.
Diastolic diameter RV/diastolic diameter LV	0.66±0.12	0.59±0.10	0.65±0.11	0.04

Three years after the intervention, TAPSE remained constant in the presence of minimal degradation of the atrial function. The number of patients with RA dilation increased from 7 patients (20.59%) at 2 years, to 13 patients (38.24%) at 3 years from the time of intervention. The number of patients with RV dilation also increased from 3 (8.82%) to 5 (14.71%). Consequently, the severity of tricuspid regurgitation also increased, from 4 (11.76%) to 6 patients (17.65%) with moderate IT and the appearance of a patient with significant IT (2.94%). In contrast, the number of patients with TAPSE <17 mm remained constant, respectively 3 cases (8.82%).

DISCUSSION

According to Di Mauro et al RV dysfunction has long-term prognostic implications in patients with surgically treated mitral valve disease, which is why it

requires early surgical treatment compared to the indications stipulated in specialized guidelines (6). The evolution of morphological and functional parameters was monitored early postoperatively, during hospitalization, at 1, 2 and 3 years after surgery.

Ye et al, in a study over 4197 patients who underwent mitral valve surgery, emphasises also a decrease in TAPSE immediately postoperative, but with improvement over the next 6 months. However, the improvement of TAPSE values was not identified at one year reevaluation (7). In our study early postoperative, we found an insignificant alteration of LV function, more resistant to operative stress, and significant RV dysfunction translated by mean TAPSE decrease from 22.20 to 14.59 mm and increasing the number of patients with TAPSE <17 mm from 15 in 25 cases, but at 1 year reevaluation TAPSE increased simultaneously with the remodeling of RV

and remained constant after 3 years in the context of minimal right atrial and ventricular morphological alterations.

Mitral valve replacement improves RV dysfunction by reducing the RV systolic pressure and also by improving TR regardless of the degree, confirmed by Desai et. al.. (8) In the present study decreased left atrial pressure due to surgical correction of mitral pathology caused a rapid regression of PH. The decrease in RV afterload also led to a regression of the severity of TR, with only one patient with moderate or severe impairment compared to 19 preoperatively. One year after surgery the changes focused mainly on the left heart, the tricuspid regurgitation suffering only a slight improvement compared to the early postoperative time by regression from grade III to grade II of one patient and the disappearance in another patient. TR degree remained constant after 2 years and showed minimal progression with the transition from grade 1 to grade 2 in 2 cases after 3 years.

Pulmonary hypertension is common before and after mitral valve surgery and we found an improvement at one year compared to the early postoperative period. The PH values remained stable at 3 years evaluation after mitral valve surgery, in accordance with a study conducted by Walls et al., which highlighted those significant decreases in the pulmonary artery pressure occurred only after Mitral valve replacement or repair (9)

One year after surgery, we found a significant decrease in the severity of heart failure with reversal of NYHA class distribution in the sense that only 10.34% of patients were in NYHA class III and none in IV compared to 89, 15% preoperatively classified in NYHA classes III and IV. The functional parameters of LV did not undergo significant changes, while the reverse remodeling of the LA continued with significant regression of the anteroposterior

diameter. In the case of RA, there were no significant changes at one year. However, we found a inverse remodeling with a decrease in the mean mid-cavity diameter of RV.

At 2 years after the intervention, we found an ongoing improvement in heart failure with only 8.33% of patients in NYHA class III compared to 12.5% at 1 year and an improvement of RV function with a regression of the mid-ventricular diameter from 31.93 mm to 31.24 mm and a decrease in the ratio of RV / LV diastolic diameters from 0.65 to 0.62 mm. However, at the 2 years evaluation we noticed a paradox, the number of patients with RA dilation increasing from 9 (18.75%) to 1 year to 15 (31.25%) at 2 years while the number of patients with RV dilation decreased from 11 to 1 year (22.92%) to 7 to 2 years (14.58%).

Three years after the intervention, the NYHA class remained stable. The number of patients with RA dilation increased from 7 cases (20.59%) at 2 years, to 13 cases (38.24%) at 3 years, and the number of patients with RV dilation also increased from 3 cases (8.82%) in 5 cases (14.71%).

Multiple studies have concluded that RV disfunction may be associated with poor functional outcomes, as well as prognostic significance, after cardiac surgery (10,11,12), especially in haemodynamic instable patients (13). The incidence of acute RV failure has been reported with variable frequency, between 0.5-30% depending on the pre-existence of RV dysfunction or the association of other risk factors (14). Regardless of the frequency, research in the literature is unanimous in asserting an association with high mortality. In the case of surgical procedures on the mitral valve, a pre-existing dysfunction is considered an independent predictor of postoperative RV failure.

CONCLUSIONS

Right ventricular systolic dysfunction is common after MV repair surgery. An improvement in RV preload and afterload in terms of decreased atrial diameters, dPmax and severity of PH was seen ppostoperatively. At 1 year, there was a significant improvement in NYHA class enrollment in parallel with the decrease in IT and PH. At the same time, a reverse remodeling of the RV began with the increase of TAPSE and the decrease of the mid-ventricular diameter. The tendency to reverse RV remodeling continued at 2 years with the constant maintenance of the severity of tricuspid regurgitation, PH and NYHA class. Three years after the intervention, a minimal dilation of the right atrium and ventricle was found with the maintenance of TAPSE stationary.

Conflict of Interest. Authors have no conflict of interest to disclose

Ethical issues. The study was approved by the Ethics Commission of the C.I. Parhon Hospital Iasi

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